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Plant Growth Regulators

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Plant growth regulators are a large group of compounds which may be totally unrelated chemically but have a pronounced effect on plant growth and development. For convenience, they may be placed into two broad classifications—growth promoters and growth inhibitors.

GROWTH PROMOTERS

In general, growth promoters stimulate growth and development, but at high concentration, these compounds may act as inhibitors for certain metabolic processes.

Hormones

Strictly speaking, hormones are naturally occurring compounds manufactured in one part of the plant, but which are usually translocated to another part of the plant and affect growth at that point. Unlike animal hormones which are synthesized in a specific organ or tissue and appear to have but a single effect, hormones in plants have multiple functions which often overlap and may complement or counteract each other. They may be involved in abcission of plant parts, direction of growth, fruit set and development, and cell differentiation.

Auxins are materials which, specifically, promote growth in length. Indole-3-acetic acid is the principal naturally occurring auxin in the plant. However, other related compounds have been isolated from plant tissue. Indole-3-acetic acid is a product of metabolism and is synthesized in the apical growing points, expanding buds, young leaves, and in the developing

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seed. While the promotion of cell elongation is the basis for determining if a material is an auxin, auxins have many other properties.

Related compounds, while not naturally occurring, may promote similar effects when externally applied to plants. One of the most widely known uses for indole-3-acetic acid and related synthetic compounds is in influencing the formation of roots on stem cuttings. Another noticeable effect is in inhibiting the growth of lateral buds. For example when the terminal bud of a chrysanthemum is removed, laterals grow because the apical growing point and young leaves, a source of auxin in inhibiting concentrations, are eliminated. Other effects of auxin are seen in tropistic movements: it is believed that plants "grow toward light" because light inactivates or destroys auxin; hence, the side of the plant away from the source of light has a greater auxin supply and thus grows more.

An interesting property of naturally occurring auxins is that they move only in a basipetal direction (downward in a normally oriented plant). Thus, even when plants are turned upside down, roots still form on stem bases because the auxins move basipetally and "collect" at the base where root initiation is stimulated.

Auxin concentrations which stimulate root formation may inhibit bud formation. Thus, auxins are usually not used on root cuttings or on leaf cuttings of some plant species or cultivars. The balance between auxins and kinins (see later) probably influences the formation of roots and shoots on most plant parts. Another example of the effect of auxin concentration is its use in fruit production. Naphthalene acetic acid, a synthetic auxin, is used for fruit thinning (cause fruit drop) and also to prevent fruit drop just prior to harvest.

Compounds chemically related to auxin such as 2, 4-D (2, 4-dichlorophenoxyacetic acid) are more properly called synthetic growth substances since they are not synthesized within the plant. The chemical, 2, 4-D, and related compounds are used commercially as weed killers and, when sprayed on the foliage of susceptible plants, cause effects somewhat similar to hormones which result in eventual death of the plant. Only certain types of plant species or cultivars may be so affected (dicotyledons or those with two seedlings leaves are highly susceptible to injury from 2, 4-D).

Root-promoting materials are chemically related to weed killers but are used at rather low concentrations. Indoleacetic acid, indolebutyric acid, and naphthalene acetamide are three chemicals commonly used to treat basal portions of cuttings to hasten rooting. Rootone and Hormodin are two proprietary materials, useful for rooting cuttings. They are not effective on certain plant species and cultivars which have naturally high auxin levels but lack certain other necessary factors for root formation.

Traumatic acid is a wound hormone which hastens cell division only in tissues that have been cut or injured.

Vitamins are complex carbohydrate derivatives, often nitrogenous, synthesized in plant tissue. Some vitamins are necessary for plant growth, notably the vitamin B complex, while others appear necessary only for ani-

mals. While vitamin B (thiamin chloride), nicotinic acid, and pantothenic acid have been shown to be necessary for the growth of roots severed from the shoot and grown in sterile culture, these compounds have not consistently promoted root growth or root initiation in intact plants. These compounds are synthesized in leaves and translocated to the roots. There is no benefit from addition of vitamins to rooting compounds or soils.

Other Hormones. Calines are a theoretical group of substances synthesized in one part of the plant which govern growth in another part. Further research will, no doubt, shed more light on this complicated area. Florigen is another postulated substance that probably exists and which may be responsible for the formation of flowers in photoperiodic, cold requiring, and other plants. Its existence has been proved by grafting experiments, but as yet, it has not been isolated. No doubt, florigen will be isolated, and, when it is, a whole new horizon will be open to those interested in controlling flower initiation.

There are several other groups of hormones that are important but cannot be discussed here because of space.

Kinins are a group of purine derivatives which have been shown to have specific effects on plants. With auxin, kinetin (a kinin) produces callus tissue. It also is similar to auxin in that it inhibits root elongation. Kinetin strongly promotes protein synthesis which auxin does weakly. It opposes auxin in that it does not inhibit lateral bud development. Also, kinins, particularly kinetin (6-furfuryl adenine), have been shown to be important in the initiation of shoots on undifferentiated tissue. As stated earlier, a balance of kinins and auxins is necessary for normal root and shoot growth in tissue culture. Kinins have also been shown to delay senescence in plants and have been investigated with reference to increasing the vase life of cut flowers and shelf life of certain vegetables. As yet, no practical applications have been discovered. Some experiments also show that the number of shoots resulting from pinching chrysanthemums can be slightly increased by kinetin applications one week prior to pinching. Further work on kinetin is necessary before it can be used commercially.

Gibberellins. There are at least 12 different gibberellins of which gibberellic acid is the most familiar to horticulturists. Gibberellins are complex compounds with fluorene, a tricyclic hydrocarbon, as a base. Gibberellins, like auxin, promote cell elongation, but, unlike auxins, exert their influence uniformly in all parts of the cell. They inhibit root formation on leaves and stems.

Though gibberellic acid has received a great deal of publicity, it has not gained much acceptance in the floral trade as a means of increasing plant size. When sprayed on leaves and stems of most cut flower crops, the increase in length as a result of the cell elongation usually results in an abnormal appearance which is undesirable. If sprayed on geranium flower heads at the time flower color is first apparent, in concentrations as low as 5 parts per million, flower head size can be increased 25 to 50 percent. Concentrations of 20 to 100 parts per million also increase flower head size but

cause such elongation of the pedicel (flower stem) that it does not support the head. Increased flower size is due to increases in the length of the flower petals.

Gibberellic acid can substitute for cold treatment on hydrangeas and azaleas, but it necessitates very frequent spraying of the foliage and is not commercially economical.

While gibberellins are not widely used in flower production, they are important in certain other areas of horticulture. Grape growers, for example, apply gibberellins as a spray to increase the number and size of berries on fruit clusters. Work with gibberellins continues, and it is probably that their further uses will be found when more research has been conducted.

GROWTH INHIBITORS

This section deals only with synthetic materials that, when applied to the plant or the soil in which its growing, will exert an inhibitory effect. Usually specific chemicals cause inhibiting effects only on selected plant species or cultivars.

Maleic hydrazide was one of the first growth inhibitors used on ornamental plants. On florist crops, it causes severe stunting or injury rather than inhibition of normal growth and therefore is not recommended for use.

Amo-1618 (2-isopropyl-4-dimethylamino-5-methylphenyl-1-piperidine-carboxylate methyl chloride) is a material that has shown greatest effect on chrysanthemums when applied as a soil drench, but it has no effect on poinsettias. Difficulties in uniform synthesis and cost have limited its commercial use.

Phosfon (2, 4-dichlorobenzyl tributyl phosphonium chloride) is a quaternary ammonium compound called a phosphonium. It is extremely effective on azaleas, chrysanthemums, Easter lilies, petunias, and rhododendrons, but inactive on China asters, geraniums, poinsettias, and pyracantha. Its mode of action is inhibition of cell division and enlargement in the subapical meristem which is that tissue at the tip of the stem. The commercial product is a 10% formulation sold as Phosfon-D (dry) or Phosfon-L (Liquid).

On azaleas, a soil drench almost completely inhibits shoot development and as a result of this check in growth, flower buds form in rather large numbers. Overdoses may result in flowers originating on dormant buds or woody portions of the stem and inhibition of the flower bud opening in the more aerial portions of the plant. The cost of treatment is high since 1 part of the 10% dry or liquid formulation is placed in 100 parts of water and 6 fl. oz. of the solution is applied to a 5-inch pot and 8 fl. oz. to a 6-inch pot. The use of B-Nine or Cycocel as a foliar spray is suggested on azaleas since either material is cheaper per plant as well as easier to apply.

Some success with Phosfon on outside container-grown rhododendrons has been reported at the U. S. Department of Agriculture, where 0.2 of a gram of actual Phosfon is applied to the soil in a 6-inch container when the shoots were 2 to 3 inches long. The plants will make several flushes of growth subsequently that season, but many shoots will be terminated with

a flower bud in the fall. The plants must be cooled for at least six weeks in order to force them for winter flowering.

On pot mums, the use of Phosfon not only decreases the ultimate height, but also causes development of darker green foliage and stiffer stems. However, it also causes a delay in flowering—from 4 to 12 days depending upon cultivar.

On pot mums, there are several ways that Phosfon can be used, but florists prefer B-Nine applied as a foliage spray since it is so much easier and quicker to apply. For Phosfon drenches, the soil must be moist at the time of application in order that the solution will be distributed uniformly over the entire soil surface; otherwise, differences will occur among the plants in a pot. Place 1 teaspoon of either the dry or liquid material in 6 quarts of water (192 fl. oz.), stir thoroughly, then apply 6 fl. oz. of this solution to each 6-inch pot, two to three weeks after pinching or two to three weeks after potting cuttings to be grown single stem. For larger pots allow 1 fl. oz. per inch diameter of pot.

On pot mums, Phosfon may be used is a more dilute form which will not cause a delay in flowering. The plants are grown with the usual recommended cultural practices (tall, medium, or short treatment), and a dilute Phosfon solution is applied the day of pinching. The solution is prepared by placing ¼ teaspoon of Phosfon D or L in 6 quarts of water (192 fl. oz.) and applying 6 fl. oz. to the soil in a 6-inch pot. The Phosfon solution that contacts the foliage should be washed off immediately to avoid development of yellow spots on the leaves.

On Easter lilies, it has the undesirable side effect of causing weak stems (necessitating staking) because of failure of cell walls to thicken.

Phosfon is a very long lasting material. When clay pots were dipped in a solution of 1 teaspoon per gallon, Phosfon has caused dwarfing of eight successive pot mum crops with no lessening of effect. When soil in a clay pot is treated, some Phosfon is absorbed in the pot wall and will influence growth of successive mum crops, hence "treated" pots must be discarded or marked to avoid difficulties.

For garden mums, a 5% dust formulation is made which can be used to keep tall growing plants compact. One quart of soil should be removed from the garden by digging a hole 5 inches in diameter and 3 inches deep. Sprinkle ½ level teaspoon of the dust formulation on this excavated soil, mix uniformly, place back in the hole, and plant one rooted mum cutting in the center of the treated area. There appears to be little carry-over effect of the Phosfon on next years plant growth.

Cycocel (2-chloroethyl trimethyl ammonium chloride) formerly called CCC, is a quaternary ammonium compound that is similar in its mode of action to Phosfon on cell division and elongation in the subapical meristem. The use of Cycocel also makes the leaves of treated plants a darker green. It is widely used in the florist trade on azaleas and poinsettias.

On azaleas, the 11.8% commercial formulation is applied as a foliar spray using 2 to 3 fluid ounces per gallon of water and spraying thoroughly to

cover the upper surface of all the foliage. Two sprays may be applied 7 to 14 days apart in order to ensure complete coverage. Further stem growth ceases almost at once and flower buds form. Although Cycocel does not in itself cause flower bud initiation, the check in growth due to its use is considered responsible for this phenomenon. After a period of two to three months during which development of the flower buds takes place, the plants are cooled (33° to 50°F) four to six weeks, then forced into flower. Year-round azaleas are now possible, but problems of cultivars best suited, time required for bud development at different seasons, length of cooling, and other various aspects need further work. The use of Cycocel causes the plant to be more "dormant" which has created problems related to length of the cooling period as well as re-growth of unsold plants. Overtreatment may so seriously stunt the plants that they may not grow following the flowering period.

On poinsettias, Cycocel may be applied as a soil drench using 1 part of the 11.8% formulation to 40 parts of water (1 quart to 10 gallons) as indicated below:

Pot Diameter (inches)	Fluid Oz. of Diluted Solution Per Pot	1 Quart of Cycocel Treats (No. of Pots)
2¼ to 3*	2	640
4	3	425
5	4	300
6	6	200
8	8	150

* Two applications necessary to apply the recommended volume to 2½-inch pots.

Application to plants in 2¼ -, 2½ - or 3-inch pots is made about two weeks after potting when the roots are well established and can absorb the material. Treatment of plants in small pots can be made up to September 15 in the North and October 1 in the South. For plants placed in the finishing pan, pot, or tub, apply up to October 15 in the North and November 1 in the South. Overdoses or later applications will cause crinkling of the bracts, but when fall weather is warm and bright, poinsettias may begin to grow undesirably tall. Treatment of the soil with Cycocel at half strength may be made as late as November 10 on taller plants to prevent undue stretching, but some diminution of bract size may result. High night temperatures negate, to some extent, the effect of Cycocel.

When applied at a 1-40 rate, the cost of the material is about 2 cents per plant plus labor of application, hence the cost for the popular size of three plants in a 6-inch pan will be 6 cents. Since profit per plant may be small, treatment should be limited to those plants propagated early which will grow too tall.

Plants treated in small pots, when shifted to larger pans but not treated, will resume the normal rate of growth when roots develop into the new

(untreated) soil. A few florists have indicated that results are as good or even better when a 1-80 soil drench is used compared with the manufacturers recommendation of 1-40, but the reasons for this variation are not known.

As a foliage spray Cycocel can be used on poinsettias to advantage. The same concentration for the soil drench can be used as a foliar spray, but some yellowish discoloration may be observed in 24 hours. Trial sprays are suggested and, if "burn" or discoloration appears, a 1-80 dilution is suggested. No spreader need be added since it is self-contained.

It is not known how long the foliar spray will last, but preliminary trials indicate that dwarfing is still evident four weeks after a spray. This probably means that plants propagated from July to mid-August may need two or three sprays and somewhat later propagated plants only one or two sprays. The first spray should be applied as soon as the plants are out of mist in order that the materials will not be washed off the foliage. If applied at the same time as the soil drench (14 days after plants are established), the sprayed plants will grow rather tall before the effects of the treatment are evident.

Do not spray wilted plants since absorption of materials may be less than if the leaves are turgid. Spraying in late afternoon is suggested, and the plants should not be syringed for 24 hours to permit maximum absorption of the material.

Sprayed plants will not be dwarfed as much as those given a soil drench. Thus, it may be safer to spray the taller growing plants late in the season when it is warm and bright rather than apply a soil drench even at half strength because some malformation of bracts may result from the drench.

Poinsettias, treated with Cycocel as a soil drench or as a foliar spray, will have darker green foliage and stiffer stems.

B-Nine (N-dimethylaminosuccinamic acid), formerly known as B-995, is the newest inhibitor. Its mode of action on the plant is similar to Cycocel. It is used on azaleas, pot mums, standard mums, pot gardenias, hydrangeas, poinsettias, some nursery stock, and bedding plants such as asters, cosmos, marigolds, petunias, and salvias. The commercial product is a 5% formulation which contains a spreader, and the concentration to apply as a foliar spray is generally 0.25% or 0.5%. To prepare a 0.25% solution place 6 fluid ounces in an empty one-gallon container and add water to the one-gallon mark. For a 0.5% solution use 12 fluid ounces. Do not apply B-Nine with any other chemicals (fertilizer or pest control materials), and do not syringe the plants for 24 hours after application. Apply to plants only when in a turgid condition since wilted plants will not absorb the material, and it is suggested that application be made in late afternoon in order that maximum absorption can occur during the first night. The material should be applied to the upper surface of fthe foliage to the point of runoff. If the material gathers in droplets on the foliage rather than spreading uniformly, add 1 to 2 teaspoons of Dreft per gallon of prepared spray, but not for poinsettias since foliage burn can be caused by added spreader.

On azaleas, it is similar to Cycocel in its effect on growth and flowering and possibly is even greater in its intensity. Handling of the plants is similar to that described for Cycocel. A 0.25% solution is suggested.

On pot mums, B-Nine has found wide acceptance from the trade because it is very effective in keeping height under control, enhancing the green color of the leaves, and strengthening the stems. No delay in flowering is experienced as is noted with Phosfon. Pinched plants may be sprayed when breaks are 1½ to 2 inches in length or, in the case of single stemmed mums, as soon as the cuttings are established and no longer wilt.

Several pot mum growers use B-Nine on the tall-growing types as follows: The plants are potted and placed under long days for 3 to 10 days depending on the season (3 days in summer to 10 days in dark winter weather). Then short days are provided and one week later the plants are soft-pinched. About two weeks after pinching, a B-Nine spray of 0.25% is applied, and, if the plants appear to be growing too tall at the time of disbudding, another spray of 0.25% is applied. In warm weather, a 0.5% concentration may be needed to keep height under control.

Cultivars of standard mums which have long pedicels can be improved by spraying the upper foliage at the time of disbudding (removal of axillary flower buds) using a 0.25% concentration. Surprisingly, flower size may be increased slightly and flower form improved.

Pot gardenias can be kept more compact by spraying a 0.5% solution in late November or early December.

Hydrangeas can be sprayed either during the "growing" period (summer) or forcing period (winter). The use of this material will make popular the cultivar Rose Supreme which is very desirable in many respects, but grows much too tall. During the summer growing period, apply a 0.5% foliar spray two to three weeks after pinching or when the shoots are 1 to 2 inches long. During the forcing period, a 0.25% spray should be applied when the leaves or the buds are unfolding and again about a week later.

On poinsettias, B-Nine can be applied as a foliar spray using a 0.25% solution. It should be applied in a similar manner to Cycocel as a foliage spray with respect to time and frequency. B-Nine as a spray appears to be a useful means of controlling height of poinsettias but it is not quite as effective as a Cycocel spraying.

Bedding plants, petunias in particular, can be kept from "stretching" either in the greenhouse or frame, or in the garden of the customer. The plants should be sprayed with a 0.25% solution when they have the spread of 1¼ to 1½ inches in diameter.

To simplify information, trade names and products have been used. No endorsement is intended, nor is criticism implied of similar products not named.

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